

Current Issue Outline 79-1



Sea-Surface Temperature And Climate

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U.S. DEPARTMENT OF COMMERCE
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SEA-SURFACE TEMPERATURE AND CLIMATE

Issue Definition

Climatic variations are likely to arise from complex interactions among the atmosphere, the oceans, and the Earth's surface. Empirical observations as well as studies using climate models have suggested that variation of oceanic conditions, especially variation in sea-surface temperatures, may be the key to understanding monthly and seasonal climatic anomaly patterns.

When air passes over the surface of the ocean, its temperature and humidity levels change. For example, cool, dry air blowing over warmer water will gain heat and moisture; the rate of gain depends on the temperature difference. The additional moisture may be released some distance away, modifying the atmospheric conditions at that point.

Thus, sea-surface temperature has the potential for producing short-term weather variations as well as long-term climatic changes.

Scientists have recorded and monitored sea-surface temperatures for many years, and their studies have linked these temperatures to subsequent weather states in an attempt to improve long-range forecasting. They have cited sea-surface temperatures (SST's) and unexpected sea-surface temperature variations (SST anomalies) as contributing factors in hurricanes, monsoons, rainfall, typhoons, length of seasons, wind patterns, and severity of winter weather.

What factors determine large-scale variations in sea-surface temperature? Several conditions are believed to be responsible:

(1) amount of solar radiation absorbed in the sea, which varies with the amount of cloud cover.

(2) evaporation and cooling, which are related to vapor pressure, temperature, and wind speed over the sea surface.

(3) depth of the mixed ocean layer affected by factors (1) and (2).

(4) heat transfer in the oceans, both horizontally in currents, and vertically through upwelling or downwelling.

Because climatic changes have such obvious and far-reaching economic, social, and political effects, any refinement in long-range forecasting capability is desirable. If we can predict climatic change on the basis of sea-surface temperature or air-sea interaction data, it becomes possible to plan the stockpiling of heating fuels well in advance of an unusually severe winter, or to plan on planting crops (such as tomatoes and certain grains) that would be economically worthwhile only if it were known well in advance that the summer temperature and rainfall conditions would be suitable.

Research on SST and Climate

SST anomalies ranging from 1° to 2° above or below normal (with extremes to 4.5° above or below normal) have been found in patches of water that may exceed 100 meters in depth and 1,000 kilometers in breadth. These unusually warm or cold patches have been observed to change rapidly in spring and fall (April - May/October - November) and often to persist throughout the winter and summer.

The specific processes by which these abnormal patches of water influence climate over the years are still not completely understood. Also, it is not yet certain whether SST anomalies initiate atmospheric changes or whether they are formed in response to such changes. The investigation of temperature and pressure relations at the air-sea boundary is a priority among oceanographers and meteorologists, who have been monitoring SST and relating the data to weather patterns in all parts of the world and to possible global climatic trends. Findings suggest an association between SST and atmospheric factors and the resulting conditions in areas located downwind or downstream.

For example, correlations have been found between SST anomalies near Newfoundland and the atmospheric conditions over Great Britain and Europe, between SST in the North Pacific and weather in Europe and the North America, between SST's in the equatorial Pacific and rainfall patterns in Australia, and between SST's in the Bering Sea and the Okhotsk high-pressure system that brings cool, cloudy weather to northern Japan.

Jerome Namias of the Scripps Institution of Oceanography of the University of California (San Diego) has done extensive research in his studies of the relation between sea-surface temperatures in the Pacific Ocean and the climate throughout the United States since the 1950's. His analysis of 26 years of SST data suggests a relationship between SST and the winter season weather patterns over the United States. He has uncovered a tendency for unusually cold SST's in the mid-Pacific, together with warm SST's off the California coast, to be associated with colder than normal winters in the eastern half of the United States and warmer than normal winters in the western half. The opposite pattern has also been observed: anomalously warm SST's in the mid-Pacific and unusually mild winters in the eastern half of the country, with correspondingly cold weather in the west. Winters were colder than normal in the east and warmer than normal in the west during 1958-71, and Namias associated marked SST anomalies with the temperature pattern change in 1958 and again in 1971, the beginning and the end of a period of unusual winter weather.

Namias has attempted to clarify the relationship between SST and climate by studying wind patterns. SST data for 26 years indicate that summer

SST's in the area of the Aleutian Islands influenced the strength, each autumn, of that vicinity's semipermanent low-pressure area known as the Aleutian low. The behavior and wind pattern of the Aleutian low have been associated with climatic conditions over North America.

Jeffery Rogers, in work done at NOAA's Great Lakes Environmental Research Laboratories at Ann Arbor, Mich., analyzed monthly SST data for the eastern portion of the North Pacific Ocean from National Marine Fisheries Service charts for January 1960 through September 1973. Statistical treatment of the data revealed three large regions of SST variability in the Pacific from 1960 to 1970. A subsequent change producing a new region coincided with the reversal in the trend toward unusually cold winters in the eastern portion of the United States (noted above). These SST areas were found to be related to fluctuations in atmospheric pressure over North America.

SST variations have been related to specific air-sea interactive weather systems such as hurricanes. C. Sergio Serra at the Institute of Geophysics in Mexico City documented the relation in the Gulf of Mexico and the north-eastern Pacific Ocean between a higher SST and the resulting decrease in surface pressure, causing an increase in a hurricane's maximum winds. When hurricanes passed over a Gulf of Mexico area containing an anomalously high SST, they were seen to intensify. Conversely, when hurricanes in the northeastern Pacific passed over the cooler waters west of the Lower California peninsula, their intensity was observed to diminish. SST anomalies in the equatorial Pacific have been related to tropical cyclonic activity; to the recurrence of the El Niño phenomenon off the coast of northern Peru, which affects fish stocks and weather patterns; and to the intensity of the rainy season in northeastern Brazil, allowing a warning of potential drought or flood conditions.

The studies cited here suggest a relation between long-term, large-scale SST anomalies and atmospheric changes, which influence weather and climate. Do these results suggest that changes in SST can be used in weather forecasting or to predict global climatic events?

A 2-week experiment using the GISS (Goddard Institute for Space Studies, NASA) model of global atmospheric circulation was performed by Jerome Spar and Robert Atlas of the University Institute of Oceanography, City University of New York. They found that using observed SST's in place of expected average temperatures in the model did not lead to any general improvement in forecasting. However, these findings are preliminary only, and they serve to highlight the need for additional research on SST's, air-sea interactions, and their relation to both short-term weather patterns and long-term climatic change.

Unanswered Questions

Current work by oceanographers and meteorologists is focused on the following questions:

- (1) How can current technology be applied to allow more accurate and efficient sampling of SST and SST fluctuations?
- (2) How are anomalous SST patches formed and later broken up, and what are their characteristic motion and longevity?
- (3) How do SST anomalies interact with the atmosphere at the air-sea boundary? What is the nature of the heat transfer mechanism at the air-sea boundary? What are the space and time scales of the interaction?
- (4) To what extent can SST be used to predict unusual weather phenomena, seasonal abnormalities, and longer term climatic anomalies? In what parts of the world might this means of prediction be found useful?

Large-Scale Research Projects

Three major research efforts in the United States are investigating these issues. NORPAX (North Pacific Experiment), based at the Scripps Institution of Oceanography, is a combined effort of research, academic, and government agencies to study ocean temperatures. FGGE (First GARP Global Experiment--GARP is Global Atmospheric Research Program) is an international project to provide a 1-year examination of the global weather system. EPOCS (Equatorial Pacific Ocean Climate Study) is a new NOAA program to study SST fluctuations in the equatorial Pacific Ocean.

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